Biaxial testing of soft tissue: a finite element analysis of protocol and fitting process

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Introduction

The use of biaxial testing setups has increased over the last decades for the characterization of soft biological, anisotropic tissues. In biaxial testing the stresses and strains in a small central region are considered homogeneous and are used for parameter fitting of a certain constitutive model of the tissue. Strain is typically measured optically with markers in this central region, as natural or artificial texture for strain mapping is difficult to obtain. Due to the small dimensions of the biological sample, suture- or rake-based gripping mechanisms are mostly used. However, the forces are applied at these gripping mechanisms in a discontinuous manner, which influences the homogeneity of central region [1] and causes errors in the parameter estimation process. This study tries to quantify this error and investigates the influence of different parameters by means of a finite element (FE) study.

Materials & Methods

Material parameters of constitutive models are determined by matching the so called model and experimental stresses. The model stresses are calculated based on the constitutive model and marker displacements. The experimental stresses are calculated based on the applied force and a section surface. Here, using a FE simulation, model and experimental stresses are compared for the determination of a correction factor which reflects the error resulting from an inhomogeneous stress and strain field.

The FE model is built in Abaqus/Standard 6.12-2 and simulates a displacement controlled biaxial test using rakes. The material of the sample is described by the GHO-material model [2], with material parameters of healthy human abdominal artery [3].-As in an actual biaxial experiment, the forces at the rakes and the displacements of the marker are tracked. With this data and with a known material model, the experimental and the model stresses are calculated and compared. A correction factor f is determined based on $\sigma_{model}=f\cdot\sigma_{experimental}$. This procedure is repeated for varying testing conditions such as varying ratio of inter-rake distance wrt sample size, anisotropy and stiffness of the material, number of rakes and testing protocol.

Results & discussion

The error between model and experimental stresses is determined by means of a correction factor for varying testing conditions. This allows to explore the influence of different parameters and to formulate a best practice for biaxial testing. A method for parameter fitting will be proposed, which takes into account correction factors and leads to improved parameter estimation. Moreover, a minimum set of geometric parameters that needs to be reported for biaxial tests will be specified to allow comparison of results in the future.

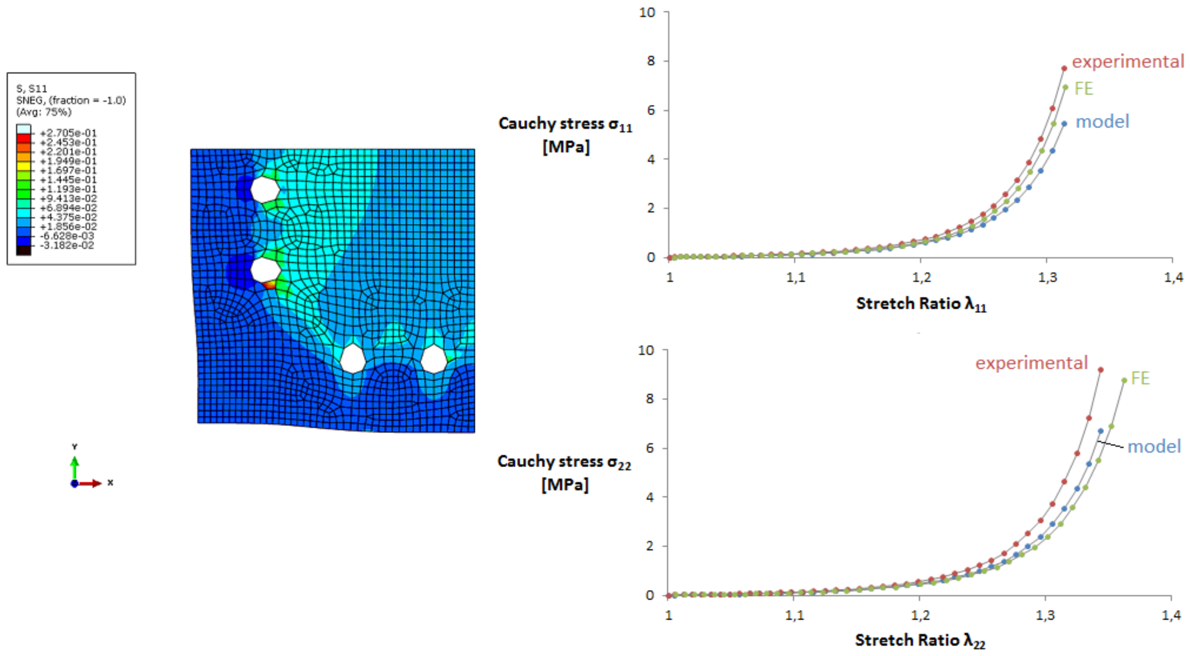

Figure: The stress field of the FE simulation is inhomogeneous (left panel). The stress-strain curves of the model and experimental Cauchy stress diverge in both 11- and 22-direction (right panel).

References

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